How Far Did Wii Run? Nintendo's Wii Fit Overestimates Distance

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March 12, 2012

Abstract

'Exergaming' (performing exercise utilizing an interactive video game) has become a popular form of physical activity. Some exergames are specifically aimed at improving or maintaining physical fitness. Yet, there is little information available to describe the accuracy of feedback given to participants. **PURPOSE:** To examine the reported run distance and exercise intensity elicited by the Wii Fit aerobic free run. **METHODS:** 500 participants ages 10-49 completed the Wii Fit aerobic free run. Oxygen consumption (VO2) was measured. Relative oxygen consumption values were used to determine estimated run distance based upon American College of Sports Medicine (ACSM) metabolic equations. Subjects rated perceived exertion using Borg's scale at a period of every 5 minutes. **RESULTS:** The Wii Fit overestimated the distance of the aerobic free run by a percentage difference of 49.9 ± 15.7 percent. The average VO_2 during the free run was 22.3 ± 5.8 ml/kg/min or 6.4 ± 1.7 METs, which is considered vigorous intensity by ACSM standards. The mean RPE recorded was 12.43 ± 2.46. **CONCLUSIONS:** The Wii Fit displays an over-estimated figure for distance when performing the aerobic free run. However, the general level of intensity in this sizeable population shows promise as a method of exercise appropriate to improve or maintain fitness in various populations.

Introduction

Physical activity is defined as any body movement produced by the contraction of skeletal muscles that results in a substantial increase over resting energy expenditure (ACSM, 2009). According to the Center for Disease Control, the national average of adults meeting the recommended amount of physical activity in 2007 was only 48.8%. In 2008, 25.4% of adults reported no leisure time at all (CDC, 2011). Most children under 13 receive adequate amounts of physical activity, however, the amounts decrease steadily in the proceeding years leading into adulthood (ACSM, 2009). Only 18.4% of teenagers from 9^{th}-12^{th} grade meeting the recommended levels of physical activity (YRBASS, 2010). Frequent participation in physical activity contributes to ones physical fitness. Physical fitness is a set of characteristics that people have or acquire, which relates to the ability to perform physical activity. Resultant health related components include cardiovascular endurance, muscular strength and endurance, flexibility, and improved body composition (ACSM, 2009). It has also been found that regular participation in physical activity can reduce the risk of several health complications including cardiovascular disease, type II diabetes, metabolic syndrome, and some cancers. Similarly, regular physical activity can also strengthen bones, improve mental health, along with mood, increase the likelihood of independent living in older adults and increase a person's chances of living longer (CDC, 2011).

Areas of the United States with high reported levels of physical inactivity also report a large number of cases of type II diabetes and obesity (CDC, 2011). Obesity is defined as having a body mass index (BMI) greater than 30. BMI is calculated by using the individual's height and weight. Although obesity itself is not a leading cause of death, it is a risk factor for many of the leading causes of death in the United States, including heart disease, stroke, diabetes, and certain cancers. There are many factors that lead to obesity, but one of the most important contributors is a lack of adequate physical activity necessary to balance caloric intake. Diabetes is a disease in which blood sugar levels are elevated. It was the seventh leading cause of death in the United States for 2009, due to the fact that it can cause serious health complications including heart disease, blindness, and kidney failure (CDC, 2012). Type 2 diabetes accounts for 90-95% off all diabetes diagnoses, and is most relevant to this population. Risk factors include, but are not limited to, older age, obesity, and physical inactivity (CDC, 2012).

With this established inverse relationship between physical activity and chronic disease/premature mortality, The American College of Sports Medicine (ACSM) established guidelines and recommendations for the amount of physical activity needed to prevent weight gain and reduce the risk for disease. Healthy adults aged 18-65 need moderate-intensity aerobic physical activity for a minimum of 30 minutes five days per week, or vigorous activity for a minimum of 20 minutes 3 days per week, along with activities that maintain or increase muscular strength and endurance for a minimum of 2 days each week. Participating in ten-minute bouts can accumulate the recommended

duration of physical activity. ACSM suggests that a minimum of moderate intensity work is necessary to improve or maintain fitness. However, increased amounts of physical activity beyond the recommended amounts will have increased health gains for the participant. For children, ACSM recommends participation in a total 60 minutes of moderate and vigorous physical activity on at least 3-4 days a week, and preferably all seven days of the week (ACSM, 2009).

Exercise is planned and structured physical activity with the goal to improve or maintain components of physical fitness. The popularity of "exer-gaming," defined as performing exercise while using a video game, is rapidly increasing among all age groups. In 2007, there was a $6.7 billion expenditure on exer-games, with the Wii fit leading the market with $2 billion in revenue and 20 million games sold worldwide (Goldstein, 2008). In relation to this boost in the video gaming market, it was found that 24.9% of high school students played video or computer games for 3 or more hours a day (YRBSS, 2010). Games such as the Wii Fit have made it possible for all ages to engage in physical activity from the comfort of their homes, while using cutting edge technology. With its innovation and convenience, the Wii Fit is being used in a variety of places. Health clubs, rehabilitation settings and nursing homes use the Wii Fit as a fun way to engage in physical activity.

Screen time is substantial among youth as well as the adult population. Technology has created opportunity for more people to have jobs, which require sitting

in front of a computer for the duration of the day. Preferred leisure time activities often involve screen time as well. With increasing rates of physical inactivity among all ages, exer-gaming may be a new technological tool used to promote physical fitness. However, the data to support this effort is lacking. As such, we have designed a study to examine physiological and perceived characteristics found when performing the Wii Fit aerobic free run. The purpose of this study is to examine the run distance and exercise intensity elicited by the Wii Fit aerobic free run.

Methods

Prior to data collection, this study was submitted and approved by the governing institutional review board as appropriate for human subjects. All subjects were familiarized with study procedures and completed consent and health screening forms prior to participation. Subjects were risk stratified according to ACSM standards as low, moderate or high risk. Only subjects stratified as low risk were permitted to participate in the study. Legal guardian's completed consent and health screening forms for children under the age of 18.

The two main objectives of the study were to determine whether or not the measured distance from the Wii Fit is accurate and whether or not the Wii Fit aerobic run would elicit an appropriate intensity to improve or maintain physical fitness.

Additionally the study evaluated qualitative measures related to participants perceptions of the Wii Fit.

Subjects

A total of 500 subjects ages 10-49 were recruited on a volunteer basis from a popular science museum in Columbus, Ohio. Subjects were either visitors of the museum or individuals who heard about the research study through other means, such as the museum website or from The Ohio State University. The gender breakdown consists of 258 male and 242 female participants. Each age group had 100 subjects. See table 1.1.

Procedure

The study was conducted in the 'Labs in Life' exhibit at the Center of Science and Industry (COSI), a large science museum located in Columbus, Ohio. Labs in Life is a collaboration between The Ohio State University and COSI providing the public with an opportunity to view and participate in real world research. Undergraduate and graduate students from The Ohio State University work with faculty members in Exercise Physiology and Nutrition in order to develop and execute research studies, which are aimed to appeal to the visitors of the COSI. The exhibit consists of three visible labs. The human performance lab, was the site for data collection in this investigation. The state

of the art research lab has large glass walls allowing patrons to view the research process as they explore the exhibit. Guests of the museum willing to participate in the study performed the exercise component during operating hours in front of other visiting guests.

The human performance lab is equipped with a flat panel television connected to a Nintendo Wii, as well as a VO_{2000} portable metabolic analyzer used to measure oxygen consumption (VO_2). VO_2 determines the volume of oxygen an individual's body tissue extracts from the blood, which increases with higher intensities of physical activity. The value results from the product of Cardiac Output and Atrial-Venous Oxygen (A-VO_2) difference. VO_2 is an objective measurement, which can be used to determine exercise intensity. Relative VO_2 is determined when the individuals body mass is considered. Relative values were utilized in this study.

All subjects used the same Mii (avatar) for the aerobic free run. Subjects were instructed to hold the Wii remote control in their hand and to walk, jog or run in place as they would in their own home setting. Those over the age of 13 completed 20 minutes of activity, while subjects aged 10-13 completed 10 minutes of activity.

Prior to testing, height and weight measurements were taken. Participants without appropriate running attire were issued shorts and a t-shirt and/or gripping socks to wear during the timed run. Oxygen consumption was measured using a

portable VO_{2000} metabolic analyzer, which was calibrated before each trial. A facemask was snugly fastened around the mouth and nose and worn for the duration of the run. A trashcan was placed approximately two feet in front of drifting participants to reduce the likeliness of moving toward the television. At completion of test the mask was removed from the subject and the average relative VO_2 measured was recorded. All testing material was sanitized, and associated tubing was pumped with air to rid of any moisture accumulated during the testing procedure.

The Wii Fit uses motion sensing technology to measure the running distance covered during the 20-minute free run. The sensor is located on top to the television, and the other transmitter is located on the remote control, which is held in the subject's hand. Algorithms used by Nintendo to calculate distance are unknown. Upon completion of the aerobic run, a final distance is displayed on the television screen. The technician recorded the final distance shown on the screen.

The subjective measurement tool used in the study, Borg's Rate of Perceived Exertion (RPE), was chosen to measure perceived intensity from the subjects. Perceived exertion is how hard you feel like your body is working based on physical sensations that a person experiences during physical activity including increased heart rate, respiration, sweating, and muscle fatigue (CDC, 2009). The RPE scale ranges from 6-20, with 6 corresponding to no exertion at all, 13 corresponding to somewhat hard, and 20 being max effort. Studies on the RPE scale have shown a strong correlation between subjects'

perceived exertion and their measured intensity of work (Eston, 2005). Subjects were given directions for the use of Borg's Rate of Perceived Exertion scale before beginning the run. RPE was described to the subjects as "1 is feeling as though you are hardly doing any work at all, and 20 is the hardest you've ever worked in your life and feel like you have to stop." Upon each five-minute interval, subjects were shown Borg's RPE scale and instructed to point to the number indicating their perceived level of exertion. The technician recorded all RPE data. At the completion of testing, an average RPE was calculated.

Participants were given a short questionnaire to gain feedback regarding subjective feelings related to their fitness level and how they feel about using the Wii Fit. The survey consisted of three questions. All questions were multiple choice. The first question asked the individual to describe their regular physical activity level (low, moderate, or high). If they indicated that they do not participate in physical activity they were finished with the survey. The second question asks how the Wii Fit exercise compared to their normal workout (easier, same, or more difficult). The last question asks how likely the individual is to use the Wii Fit regularly if they were given one. 'I Don't Know' was an acceptable answer for this question.

All recorded data was organized in an Excel worksheet. Relative VO_2 values were inserted into ACSM metabolic equations to determine distance. VO_2 values were converted to metabolic equivalents (METS). Each MET is equivalent to a VO_2 of 3.5 mL/kg/min (resting metabolic rate). The ACSM walk equation was utilized for MET values below seven (VO_2=3.5*speed). The ACSM running equation was utilized for MET values seven and greater (VO_2=3.5+0.2*speed). Vertical components were eliminated from the equations as the study was conducted in place on a level surface. Speed was replaced with distance over time, which left distance as the only unknown variable. Statistics compared variables of interest using paired sample t-test. Descriptive statistics were used to examine percentage differences.

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Results

Distance: There was a significant difference (p=.000) in comparing the Wii Fit aerobic run to the calculated distance. The Wii Fit aerobic free run over-estimated the distance by a mean percentage difference of 49.9 ± 15.7. The youngest age group, in which the Wii estimated a 55.4 ± 12.1 percent higher distance than what was calculated, recorded the largest inaccuracy (Figure 1.2). The relationship between reported and calculated distance improved somewhat with age, revealing the oldest subjects aged 40-49 to have the lowest percent difference of 45.8 ± 15.5. The higher imprecision in young

children may be due to movement of the upper body out of rhythm with the lower body, in an effort to make the avatar run faster.

VO2: ACSM classifies light physical activity to be below 3 METS, moderate activity between 3-6 METS, and vigorous activity 6 METS or more (ACSM,2009). The mean VO_2 for all subjects was 22.3 ± 5.8 ml/kg/min (6.4 ± 1.7 METs), which is considered vigorous intensity by ACSM standards. There are many contributors to VO_{2max} including age, genetics, disease, and the amount of aerobic training incorporated into ones routine. Thus, true intensities will vary from person to person. Typically VO_2max decreases with age beginning in the thirties or forties. Considering that the older individuals in the study had a similar VO_2 as the college aged subjects, a higher relative intensity level occurred in the older adults. At any age, highly trained athletes have a much higher VO_2 compared to a sedentary person of the same age. Therefore, a MET value of 6 (VO_2=21 mL/kg/min) would not be considered vigorous intensity in a trained individual. The average VO2 scores are shown below for each age group. See Table 1.2.

RPE: The mean RPE reported for all subjects was 12.43 ± 2.46. This RPE corresponds to a level of exertion "between light and somewhat hard". ACSM recommends a target RPE range from 12-16, with 12 representing a moderate level exercise. See table 1.3

Qualitative Survey Results: Posttest questionnaire results indicated that, overall, subjects were more likely than not to use the Wii Fit on a regular basis. The highest likeness level was reported from the 10-13 year olds. The least likely to use the Wii Fit regularly was reported by the 18-29 year olds. Overall the subjects reported that they were moderately active and felt that the Wii Fit was easier than their normal workout.

Conclusion

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The youngest children in the study reported the highest partiality for the Wii Fit exer-gaming experience. Although the 10-13 year olds percentage difference from actual distance was the highest, possibly due to an effort to cheat the game, they also experienced a vigorous intensity exercise. With increasing obesity rates in children, and an interest in video games, the Wii Fit may be an effective method to interest the underactive child.

When comparing measured intensity (VO_2) to perceived intensity (RPE), it was found that most subjects achieved a higher intensity than they perceived. It is important to note that the corresponding intensity value does not take into consideration VO_2 max. Maximal Oxygen Uptake (VO_{2max}), is the VO_2 measured when an individual is working at the highest possible intensity and is indicative of cardiorespiratory fitness. Comparing the measured oxygen consumption from the trial to maximal oxygen consumption levels would give a true value of intensity. Therefore, vigorous intensities

would only apply to the general population, in which case the Wii Fit may provide a more pleasurable experience while taking away from high levels of perceived exertion in adults and children.

The Wii Fit displays an overestimated figure for distance on the aerobic free run, however, it is not discouraged for the sedentary population to engage in exer-gaming, as the Wii Fit did elicit a moderate to vigorous intensity level. Considering the aerobic capacity of a more experienced endurance athlete, this MET level will elicit a relatively low intensity workout; therefore, exer-game running should not replace other modes of training in a more active population.

It may be useful to repeat the study on the newly updated Wii Fit Plus. Although it is uncertain whether or not the algorithms or motion-sensing device has been altered, the newer model provides a MET measurement to the user. This would give the investigators the ability to directly compare the value without using ACSM metabolic equations to solve for a distance.

Interestingly, many subjects reported that the Wii Fit felt easier than their normal workout. Their perceived intensities were much lower than their actual intensities. Considering that the distance displayed on the screen was twice as high than the actual distance, it would be interesting to investigate how the exaggerated value affected their psychological perception of exertion. When the subjects see an

overestimated distance, they may consider the amount of fatigue that they normally expect to feel at that mileage marker. Comparing their expected exertion level to their current exertion level may lead them feel as though they are doing better than usual. In turn this may motivate them to continue. It would be interesting to examine whether or not exaggerated performance values are a motivating factor in exer-gaming. This idea ties into mastery experiences increasing self-efficacy in social cognitive theory. Should it be found that exaggerated figures promote motivation, the information found may not be directly useful, as it could be dangerous. To fool one into believing they ran an incredible distance would give them a false sense of fitness, and may lead them to believe that they are prepared and trained for an event that they are only partially prepared for.

Table 1.1

Subjects	Male	Female
Age 10-13	58	42
Age 14-17	52	48
Age 18-29	59	41
Age 30-39	47	53
Age 40-49	42	58
Total	258	242

Age and sex distribution of the 500 participants

Table 1.2

Subjects	Mean VO_2	Standard Deviation
Ages 10-13	25.8	5.7
Ages 14-17	21.9	5.2
Ages 18-29	21.7	5.9
Ages 30-39	20.4	5.3
Ages 40-49	21.9	5.9
All	22.3	5.8

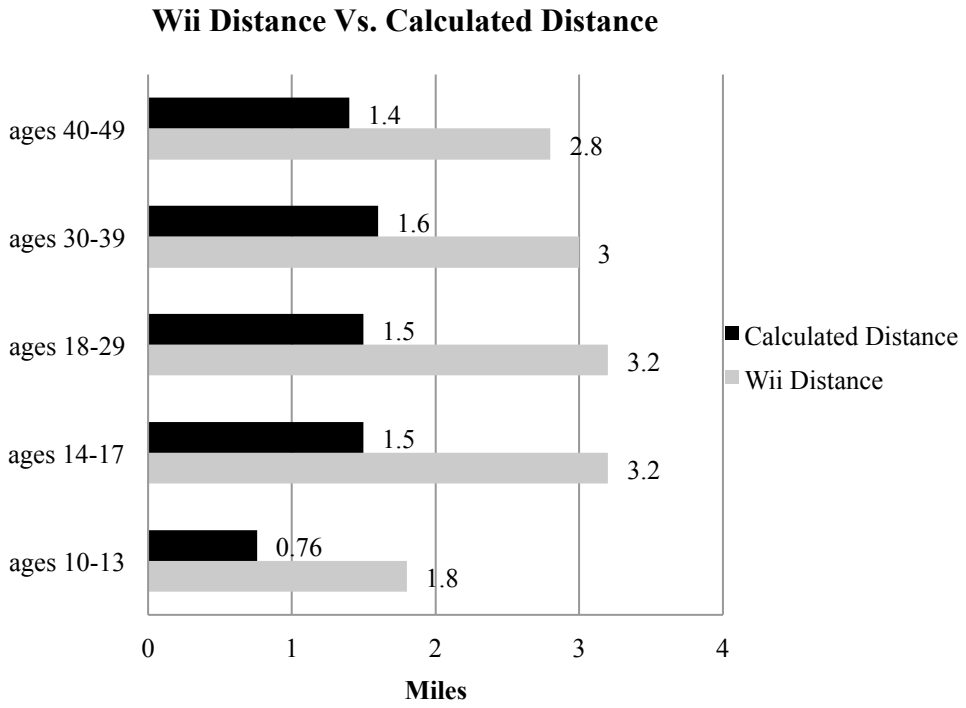
Results of mean relative measured VO_2 per age group

Table 1.3

Subjects	Mean RPE
Ages 10-13	13.12
Ages 14-17	12.28
Ages 18-29	11.91
Ages 30-39	12.33
Ages 40-49	12.28
All	12.4

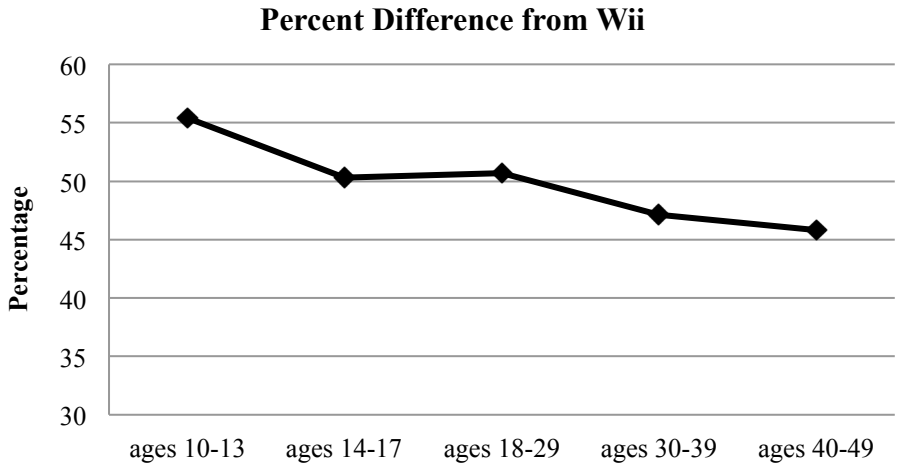
Mean RPE recorded for each age group

Figure 1.1



Calculated distance (determined from VO_2 measurement values inserted into ACSM metabolic equations) compared to the distance displayed on the screen measured by the the Wii Fit

Figure 1.2



The percentage difference from the Wii distance indicating how much higher the Wii distance is in comparison to the measured distance based on VO_2 and ACSM metabolic equations

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